12. The precautionary principle and early warnings of chemical contamination of the Great Lakes

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12.1. The first significant early warnings

The growth of chemical manufacturing and use of organochlorine compounds in the 20th century has resulted in global contamination with a wide variety of toxic and persistent organochlorine residues. Probably the most significant 'early warning' was the publication of *Silent spring* by Rachel Carson (1962). This book compiled the existing evidence of previous early warnings of the effects of organochlorine pesticides on fish and wildlife and warned particularly of the threat posed by these chemicals in relation to cancer in humans.

One area of North America where the scientific and policy implications of organochlorine contamination have been intensively studied, particularly since the publication of *Silent spring*, is the Great Lakes basin. The United States and Canada share a boundary in four of the five Great Lakes. Early warnings of the contamination of this large ecosystem came from a variety of sources, not only as chemical analytical observations of the presence of residues of these organochlorine compounds, but also as observations of effects on populations of wild organisms, and particularly predatory birds.

The first analytical results of the presence of organochlorine compounds in organisms in the Great Lakes were published by Dr Joseph Hickey and co-workers and concerned the bioaccumulation of DDT (dichlorodiphenyl trichloroethane) and metabolites, and dieldrin in a Lake Michigan food chain (Hickey *et al.*, 1966). Additional organochlorine pesticides including lindane, heptachlor, aldrin and endrin were identified in samples of Lake Erie water (Pfister *et al.*, 1969). After the discovery of polychlorinated biphenyls (PCBs) in a white-tailed sea eagle in Sweden (Jensen, 1966), analytical methods were developed to detect the presence of PCBs (Reynolds, 1969) in Great Lakes samples. Subsequent application of these methods led to the finding of hexachlorobenzene in samples of eggs of common terns from Hamilton Harbour, Ontario (Gilbertson and Reynolds, 1972). The flame retardant and pesticide mirex was subsequently identified in fish sampled from Lake Ontario (Kaiser, 1974).

The first reports of the effects of organochlorine compounds on Great Lakes populations of birds were those of Dr Joseph Hickey's students and co-workers (Keith, 1966; Ludwig and Tomoff, 1966) who documented the effects of DDT and metabolites, and dieldrin on reproduction and mortality in Lake Michigan herring gulls. Previous observations of the decline in the population and reproductive failure of Florida bald eagles had been published (Broley, 1952; Broley, 1958) but research on Great Lakes bald eagles did not start until the mid-1960s, by which time most of the population had been destroyed (Sprunt *et al.*, 1973). The first observation of changes in eggshell quality was reported by naturalists visiting Pigeon Island in Lake Ontario in 1963 (Edwards *et al.*, 1963) when two soft-shelled eggs were found in the nest of a pair of double-crested cormorants. The first published observation of a deformed chick of a Great Lakes fish-eating bird was of a juvenile bald eagle (Grier, 1968). Systematic studies of the incidence of deformities in the chicks of various species of colonial fish-eating bird were undertaken in the early 1970s (Gilbertson *et al.*, 1976). In the mid-1960s, there was an outbreak of adult and kit mortality in ranch mink that fed on fish from the Great Lakes that had serious effects on this economic activity (Hartsough, 1965).

Concerns about the possible effects of organochlorine compounds on human health were first addressed in 1974 in a cohort of Great Lakes fishermen (Humphrey, 1983). Consumption of contaminated fish resulted in elevated levels of PCBs in humans but was not associated with any recognised acute effects in fish eaters. These concerns were heightened in the spring of 1978, when Lois Gibbs, a resident living in a housing development built next to the Love Canal, Niagara Falls, New York started to investigate

the incidence of diseases in her community and the possible relationship to the 20 000 tonnes of toxic wastes that had been disposed of in the canal by the Hooker Chemical Company during the previous 20 years. These inquiries set off a series of psycho-social dynamics within families, among workers, and between communities and institutions such as the local university, hospitals, churches and the medical profession (Levine, 1982). Out of desperation, Lois Gibbs organised her neighbours into the Love Canal Homeowners Association and struggled for more than two years for relocation. Opposing the group's efforts, though, were the chemical manufacturer, Occidental Petroleum which had bought the Hooker Chemical Company, and local, state and federal government officials who insisted that the leaking toxic chemicals, including dioxin, the most toxic chemical known, were not the cause of high rates of birth defects, miscarriages, cancers and other health problems. Finally, in October 1980, President Jimmy Carter delivered an Emergency Declaration which moved 900 families from this hazardous area and signified the victory of this grassroots movement. In 1981, Lois Gibbs responded to the growing public perception of the pervasive nature of the contamination and created the Center for Health, Environment and Justice (formerly Citizens Clearinghouse for Hazardous Wastes), an organisation that has assisted more than 8 000 grassroots groups with organisational, technical and general information nationwide.

In 1980, based on the concerns raised in the preliminary studies of elevated levels of PCBs in fish eaters as well as the concerns at the Love Canal, a cohort of infants was established to investigate the developmental effects of maternal consumption of Lake Michigan fish contaminated with persistent toxic substances. At birth, infants exposed to the highest levels of PCBs weighed less and had smaller head circumferences (Fein *et al.*, 1984) and exhibited one or more behavioural deficits (Jacobson *et al.*, 1984). Subsequent assessment and testing indicated that the growth retardation was irreversible, and that there were effects on short-term memory at seven months and at four years, and effects on attention (Jacobson *et al.*, 1990; Jacobson and Jacobson, 1993). Testing at 11 years of age indicated that the children most highly exposed *in utero* had IQ scores that were more than six points below the reference group (Jacobson and Jacobson, 1996). The strongest effect was on memory and attention, and the most highly exposed children were three times more likely to have low average IQ scores and twice as likely to be at least two years behind in reading comprehension.

12.2. Date and nature of subsequent action or inaction

The information about the presence and effects of organochlorine chemicals in the Great Lakes in the 1960s had been foreshadowed not only by the publication of *Silent spring* in 1962, but also by surveys in the United Kingdom of the risks to workers applying pesticides (1951), residues in food (1953) and risks to wildlife (1955) (cited in Cook, 1964). In 1961 the authorities decided on a voluntary ban on the use of aldrin, dieldrin and heptachlor for seed dressing for spring-sown cereals. Further restrictions were decided in 1964 based on the observations of high mortality of seed-eating birds and the widespread decline of the peregrine falcon (Ratcliffe, 1972). These moves were opposed by the Shell Chemical Company which stated (Robinson, 1967): 'the correlations between the time of usage of aldrin/dieldrin and the declines in populations are difficult to assess as there is insufficient quantitative data which can be used to establish precise relationships for any of the raptor species. It is impossible from these surveys to establish, in a rigorous manner, the nature of the relationship between the usage of aldrin/dieldrin and the breeding status of the peregrine falcon.'

This scepticism was mirrored on the other side of the Atlantic. Linda Lear (1997), in her biography of Rachel Carson, has detailed the intense controversy surrounding the use of organochlorine pesticides in the 1950s and 1960s and the partisan review of the US National Academy of Sciences National Research Council in its highly controversial report entitled 'Pest control and wildlife relationships'. The serialised publication of parts of *Silent spring* in the *New Yorker* in 1962 resulted in a letter from general counsel of the Velsicol Chemical Company to Houghton Mifflin, publisher of *Silent spring*, threatening legal action unless the last instalment in the *New Yorker* was cancelled (Lear, 1997). After publication of *Silent spring*, the National Agricultural Chemicals Association (NACA) produced and distributed a critical information booklet entitled 'Fact and fancy' and sent it with letters to editors of magazines

and newspapers indicating that future advertising revenues might be affected if *Silent spring* were to receive favourable reviews (Lear, 1997).

In November 1963 there was a massive fish kill in the lower Mississippi River that was eventually traced to the organochlorine pesticide endrin and its chemical manufacturing by Velsicol Chemical Company at Memphis. The political response was to stimulate the production of a draft Clean Water Bill and a precautionary ruling by Stewart Udall as Secretary of the Department of the Interior prohibiting the use of pesticides where there was a reasonable doubt about safety (Lear, 1997). But even four years later, the Shell Chemical Company (1967) published a report that stated: 'The implication of endrin in the 1963 Mississippi River fish kill has not been verified by recent studies'.

The authorities in the United States were reluctant to take action and the US Department of Agriculture responsible for registration of pesticides tended to align itself with the pesticide manufacturers and the farmers. A suit brought by Victor Yannacone in 1966 on behalf of the Brookhaven Town Natural Resources Committee to stop the use of DDT by the Suffolk County (Long Island, New York) Mosquito Control Commission, led to the formation of the Environmental Defense Fund in 1967. This group of lawyers, scientists and economists eventually brought a suit against the US Department of Agriculture, first in Wisconsin and subsequently in Washington, DC, to cancel the registration of DDT. Responsibility for pesticide registration was transferred to the newly formed US Environmental Protection Agency, and the Environmental Defense Fund suit eventually led to judicial administrative decisions to suspend the registrations of DDT, in 1972, and dieldrin, in 1973. In Canada, Professor Donald Chant (1969), on behalf of the newly formed Pollution Probe at the University of Toronto, successfully petitioned the Minister of Health and Welfare and the Minister of Agriculture to ban DDT and related pesticides. These national decisions had an immediate effect on the concentrations of organochlorine pesticides in the Great Lakes environment that was reflected in gradual improvements in the status and reproduction of bald eagles (Grier, 1982).

Other national and international decisions were being made that affected the concentrations of organochlorine compounds in the Great Lakes. The 1972 Federal Water Pollution Control Act laid the groundwork for regulating pollutant discharges into US waters. In Canada, the 1970 revisions to the Fisheries Act were being used to implement federal controls on water pollution. In 1970, Monsanto, as the sole manufacturer of PCBs in North America, announced that it was restricting the sale of PCBs for open uses, such as adhesives, sealants, chlorinated rubber, special paints and fire-resistant hydraulic fluids (Monsanto, 1970).

At the regional level, the governments of the United States and of Canada had referred the matter of the pollution of the lower Great Lakes to the International Joint Commission (IJC). While the primary concern in the 1960s was eutrophication of the Great Lakes, particularly Lake Erie, the report of the IJC (1969) drew attention to the presence of organochlorine compounds in fish and wildlife. The report led to the negotiation of the 1972 Great Lakes Water Quality Agreement signed by President Nixon and Prime Minister Trudeau. In the 1970s, new information about the presence and effects of persistent toxic substances in the Great Lakes was affecting the political and regulatory processes in both countries. For example, the finding of mirex in Lake Ontario fish (Kaiser, 1974) led to a New York State prohibition of the possession of fish caught in Lake Ontario. This precautionary approach was, however, met with such flagrant violation of the regulation that it was rescinded after only a few months.

Similarly, when the Great Lakes Water Quality Agreement was renegotiated in 1978, it included a precautionary policy which stated that 'the discharge of any or all persistent toxic substances be virtually eliminated'. However the politics of the 1980s were very different, in both countries, from those of the 1970s when the Great Lakes Water Quality Agreement was renegotiated. The statements about the effects of persistent toxic substances on Great Lakes wildlife and humans were met with scepticism by government officials and demands for proof of a causal relationship before 'massive' appropriations and expenditures of public or private funds on remedial works.

12.3. Consequences of institutional responses

The past 30 years have been a period in which these institutional responses have led to significant improvements in water quality in the Great Lakes and particularly in relation to decreases in the sources, loadings and concentrations of persistent toxic substances. Early in the process, indicator organisms, such as lake trout and the eggs of herring gulls (Pekarik and Weseloh, 1998) were selected and analysed to follow the trends in concentrations. The evidence from these analyses demonstrate that the concentrations decreased markedly between about 1975 and the early 1980s (Stow *et al.*, 1999). The trends in concentrations have generally followed a first order decline, and while technically the decreases continue at the same logarithmic rates, in practice the curves have become non-zero asymptotes at concentrations that are still of toxicological significance.

For example, the present concentrations of PCBs in water are about two orders of magnitude higher than the established water quality criterion for the protection of human health based on a cancer risk assessment. The changes in the politics in both countries in the 1980s do not seem to have led to the level of control of releases of organochlorine compounds or to the clean-up of non-point sources, such as contaminated landfill sites, sediments and atmospheric emissions, that are required to protect human health. The question remains whether present levels are affecting human development and whether the effects are serious enough to warrant implementing the stringent requirements of the Great Lakes Water Quality Agreement, particularly concerning restoration of water quality.

In 1990, the late Dr Helen Daly set up a team to replicate the Lake Michigan epidemiological studies by establishing a cohort centred on Oswego, New York and comprised of infants whose mothers had eaten Lake Ontario fish. While the researchers did not find the same relationship between maternal fish consumption prior to pregnancy and effects on body weight and head circumference, the same behavioural effects were observed (Lonky *et al.*, 1996). In addition, based on rat studies (Daly, 1993), it was shown that the infants of the mothers with the highest fish consumption could not adapt to frustrating events. Subsequent chemical analytical determinations have shown the specific relationship between these behavioural anomalies and prenatal exposures to the highly chlorinated biphenyls (Stewart *et al.*, 2000).

To address the pervasive scepticism of the 1980s and 1990s, a small group of scientists started applying new methods (Fox, 1991) for integrating evidence to infer causal relationships between the observed injury to wildlife and human health and exposures to persistent toxic substances. This process has resulted in a series of case studies linking the effects in a variety of organisms, including humans, with specific chemical causes (reviewed in Gilbertson, 1996. There has, however, been a variety of objections to this approach. For example, O'Brien (1994) has objected that the approach is not precautionary. The precautionary principle is, by definition, applicable to circumstances in which there is a high degree of uncertainty. The application of this *a posteriori* process is designed to reduce uncertainty using all the existing evidence to infer a causal relationship, thereby precluding the special need for applying the precautionary principle.

Similarly, the application of post-normal science (Funtowicz and Ravetz, 1993) to the implementation of the Great Lakes Water Quality Agreement, based on the premises of system complexity and uncertainty, has recently resulted in a singular legitimacy for multi-causal ecological statements (Shear, 1996; Hartig *et al.*, 1998; Donahue, 1999). This supposed complexity and uncertainty has not been inconvenient to those interests reluctant to implement the costly remedial policies contained in the Great Lakes Water Quality Agreement. In contrast, the causal statements of the toxicologists are based on the integration of a diversity of evidence drawn from traditional science based on simple linear systems. These yield, first, a high degree of certainty, and thus dispense with the need to apply the precautionary principle. Second, the causal relationships could be used as a reliable and scientifically defensible basis for remedial action to restore water quality. This is particularly valuable in situations, such as the Great Lakes, where water quality has been chronically impaired by releases of persistent toxic substances and where organisms, including humans, have already been injured over a long period of time. Remedial actions, based on these

statements, to address the extensively contaminated sediments and to secure the leaking chemical landfill sites, could be precautions against the production of another generation of infants prenatally exposed to chemicals that profoundly alter structural and functional development (Colborn and Clement, 1992; Colborn *et al.*, 1998). In this sense, there is a powerful cognitive dissonance between the scientific information produced during the past 20 years on the injury to health (Johnson *et al.*, 1998 and 1999) and the response of governments to implementing the policies contained in the Great Lakes Water Quality Agreement.

12.4. Costs and benefits

What have been the costs and benefits of these actions and their distribution across time? There have been significant improvements in the past 20 years in the development and application of methods for estimating costs and benefits in relation to chemical pollution (see, for example, Swanson and Vighi, 1998). A few cost and benefit analyses have been undertaken of the effects of persistent toxic substances in the Great Lakes and of their removal from discharges, contaminated landfill sites and sediments. For example, Burtraw and Krupnick (1999) have described methods to measure health benefits in monetary and non-monetary terms in the context of reductions in pollutants as part of a programme to improve Great Lakes water quality.

In the development of the Great Lakes Water Quality Guidance (US EPA, 1993) under the Clean Water Act, there was an analysis of the costs and benefits. Incremental costs were calculated for additional construction of treatment facilities and process changes including pollution prevention and waste minimisation programmes; for additional monitoring programmes; and for pre-treatment programmes. These were evaluated for 316 major municipal dischargers, 272 major industrial dischargers and 3 207 minor dischargers using four different scenarios. Non-point sources were not covered. The total annual costs of compliance in the United States were estimated in 1992 to be between USD 80 and USD 200 million (ca. EUR 80–200 million) depending on the scenario.

The Detroit Wastewater Treatment Plant is one of the largest point sources to the Great Lakes and discharges more than 100 kilograms of PCBs per year. Since 1971, nearly USD 1 billion has been spent in upgrading the sewer infrastructure and USD 120 million was recently spent in improving the operation through construction of a pumping station. There are plans for additional improvements costing USD 1 billion, including an increase in the primary treatment capacity. Whether these costs will result in improvements in the PCB discharge from the plant is uncertain.

There are also a few studies of the costs and benefits of remedial actions for chemical landfill sites. One study was undertaken (Sudar and Muir, 1989) concerning the leaching of organochlorine pollutants from four of the largest dump sites located next to the Niagara River, upstream from Lake Ontario. The following three options were examined: no action; containment; and removal and thermal destruction, with consideration of short and long time horizons, and from the viewpoint of who pays and who benefits, with different discount rates. The cheapest option is containment, through capping the waste site and collecting and treating the contaminated groundwater, involving costs of USD 100 million with a 10-year horizon, and nearly USD 300 million with a 35-year horizon. This option essentially leaves the problem to another generation. The most expensive option is also containment with leaks that, over a 100-year horizon, would cost more than USD 19 billion. The removal and thermal destruction option for the four sites would entail capital expenditures of about USD 50 million and annual operating costs of about USD 75 million for 15 years. The no action option, over 35 years and 100 years, respectively, would cost society more than USD 1 billion and 16 billion. These same costs to society would be involved if industry spent about USD 300 million over 35 years or USD 3 billion over 100 years and was unsuccessful in stopping the plumes from reaching the face of the Niagara Gorge. These estimates were for four dump sites, but there are several hundred around the Great Lakes basin that are leaking persistent toxic substances.

The Great Lakes Science Advisory Board of the International Joint Commission recently toured nine of the hazardous waste sites in the Niagara Falls area. Extensive engineering work has been successfully undertaken to

intercept and treat contaminated groundwater leachate from the hazardous waste sites and prevent movement to the Niagara River and to Lake Ontario. However, these are costly systems to construct and maintain. For example, at the Occidental Chemical Corporation's Hyde Park hazardous waste site between 1998 and 2000, some 100 million gallons of water (ca. 375 million litres) were intercepted and treated, and between 1989 and 2000, nearly 300 000 gallons of non-aqueous phase liquids (ca. 1.135 million litres) were collected and destroyed. The annual operation and maintenance costs at this site alone are USD 2 million. Many of the remedial costs borne by the industries are unavailable, but available remedial costs to industry and governments, incurred to date for the New York landfill sites, are at least USD 370 million. Remediation costs at New York hazardous waste sites are expected to total over USD 630 million (US EPA and NYSDEC, 2000). There is a need for estimates of the benefits that will accrue from remedial actions at these and at other sites around the Great Lakes, or public and political support for these costly schemes is likely to wane.

The costs of remediation of contaminated sediment in the US part of the Great Lakes have been detailed (US EPA, 1998) with about USD 580 million spent on 38 sediment remediation projects since 1985. However this only represents a small fraction of work necessary. Costs of remedial work for the Outboard Marine Corporation site at Waukegan, in Illinois, were USD 21 million to remove 136 000 kilograms of PCBs from OMC property. A further 900 kilograms of PCBs is in the navigational channel and will be removed starting in 2002, at an estimated cost of USD 12–14 million which will include construction of a confined disposal facility. Similarly, estimates for treatment costs for remedial work on the sediments of Hamilton Harbour range from CAD 60 million to 1 billion. There seem to be few benefits analyses to supplement these cost estimates.

12.5. Conclusions and lessons for the future

The Great Lakes have provided a valuable if unwitting laboratory for studying the effects of organochlorine compounds, not only on the health of wildlife and humans, but also on the political responses to pollution of large ecosystems with persistent toxic substances. The record indicates the extraordinary lengths of time between the introduction of a new technology, the detection of an effect, the demonstration of a causal relationship, and the appropriate and sufficient response from the authorities (Lawless, 1977). It is only after more than half a century of exposures to organochlorine compounds from the Great Lakes that scientists are beginning to comprehend the scale of damage that occurred to human health and to wildlife.

Over this long period of time, scientists have been faced with a dilemma of whether, on the one hand, to investigate injury to populations of fish, wildlife and humans suspected to have been caused by persistent toxic substances, or to make a special plea to stop the sources and exposures even though they originally had little more than a suspicion. Ironically, even though a causal relationship has now been proven between the injury to health and exposures to persistent toxic substances, Great Lakes scientists have found it difficult to communicate their scientific evidence within the social, economic and political contexts in which their work is undertaken to effect remedial actions. These various case studies demonstrate that the length of time between the introduction of a new technology, product or undertaking, the discovery of its deleterious effects, and the regulatory, judicial or administrative action to reduce exposures, is seldom less than 25 years.

The existing evidence concerning the persistence of the organochlorine compounds released into the Great Lakes during the past 60 years indicates that it will probably be several more decades before the necessary remedial actions will have reduced concentrations sufficiently to protect human reproduction and development from chemically induced injury, particularly from consumption of contaminated Great Lakes fish. The scientific aspects are characterised by a high degree of certainty. In essence, we are engaged in the trans-generational transmission not only of the legacy of contamination and the associated dilemmas, but also of chemically induced injury to the structural and functional development of exposed infants. But for the health, fisheries and environmental researchers and administrators there is a complex array of social, economic and political dilemmas. For example, should health administrators draw attention to the contamination and recommend that children and women of

child-bearing age should not eat Great Lakes fish, or would this advice jeopardise commercial, sport and tribal fisheries interests? Similarly, should health and environmental researchers report on the injury to fisheries and wildlife populations, and on the injury to human health from the continuing exposures to elevated concentrations of persistent toxic substances? Or would the requisite response to this information by the environmental administrators represent an apparently impossible financial burden for the US and Canadian taxpayers?

Table 12.1. **Great Lakes: early warnings and actions**

Source: EEA

1962	*Silent spring* by Rachel Carson is the significant early warning of the effects of organochlorine pesticides on fish and wildlife as well as the threat of cancer in humans
1963	First observation of changes in eggshell quality on Pigeon Island in Lake Ontario
1966	Hickey *et al*. publish the first analytical results of the presence of organochlorine compounds in organisms in the Great Lakes
1969	DDT and related pesticides are banned in Canada
1972	DDT is banned in the United States (dieldrin is banned in 1973) and gradual improvements in wildlife begin in the Great Lakes
1974	Concerns of possible effects of organochlorine compounds on human health
1978	Association of incidence of diseases (high rates of birth defects, miscarriages, cancers, etc.) in Love Canal, Niagara Falls with the disposal of toxic wastes (including dioxin) denied by Hooker Chemical Company
1978	Renegotiation of the Great Lakes Water Quality Agreement, including a precautionary policy, but it is not properly implemented
1980	President's Emergency Declaration moves 900 families from the hazardous Love Canal area
1984	Studies show that, at birth, infants exposed to high levels of PCBs (maternal consumption of Lake Michigan contaminated fish) weighed less and had smaller heads
1996	Studies of Lake Ontario affected children published that observed same behavioural effects as in affected children from Lake Michigan
2000	The specific relationship between behavioural anomalies and prenatal exposures to the highly chlorinated biphenyls is determined
2000	Reluctance to undertake costly remedial actions even after causal relationship is proven

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